Foundations of Modern Networking

SDN, NFV, QoE, IoT, and Cloud

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Chapter 2

Requirements and Technology

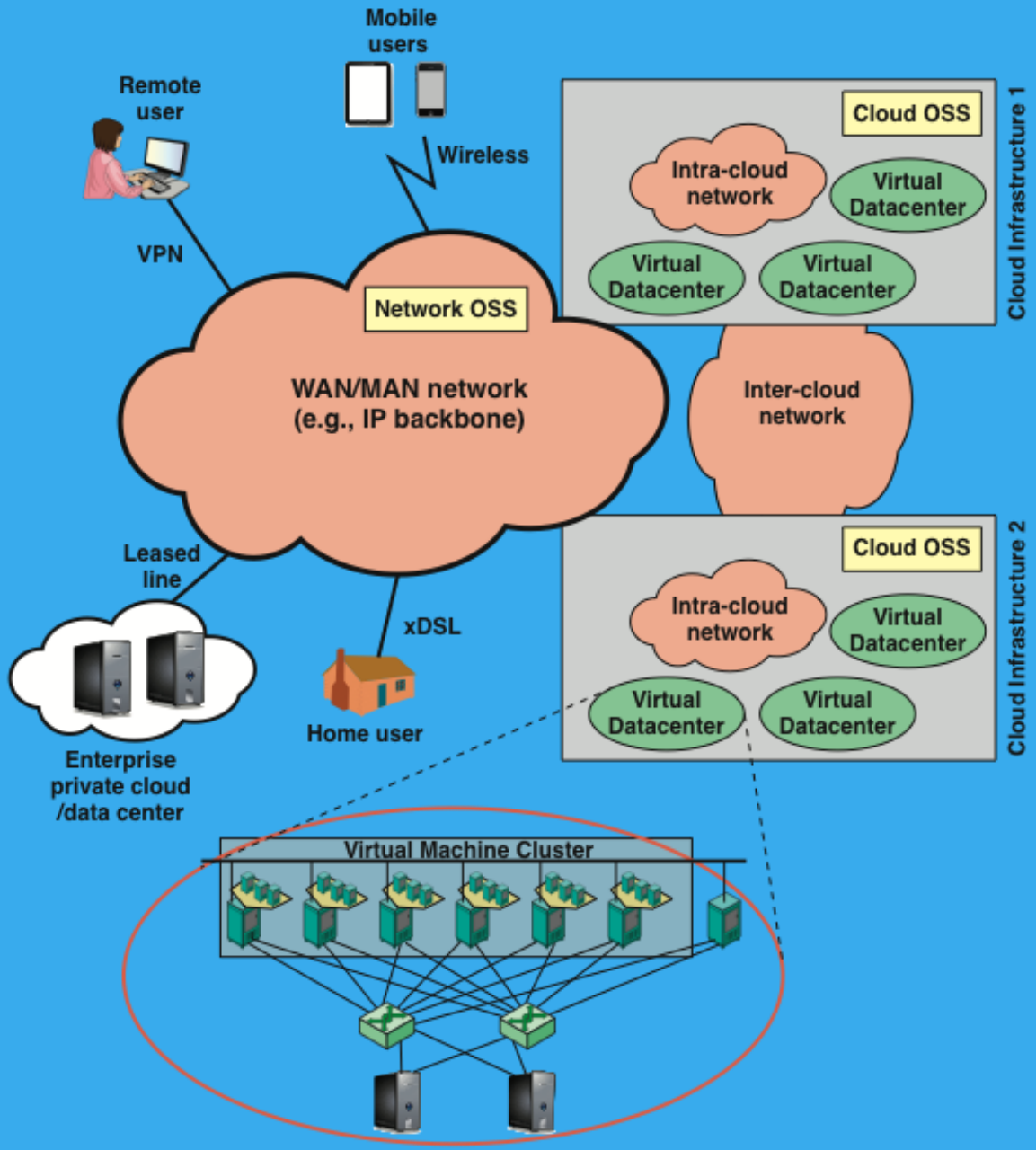

Figure 2.4 Cloud Network Model

Cloud Computing

- Intracloud, intercloud, core, together with the OSS components, are the foundation of cloud services composition and delivery
- Functional requirements for this network capability:
  - Scalability
    - Networks must be able to scale easily to meet the demands of moving from current cloud infrastructures of hundreds or a few thousand servers to networks of tens or even hundreds of thousands of servers
  - Performance
    - Traffic in both big data installations and cloud provider networks is unpredictable and quite variable
  - Agility and flexibility
    - The cloud-based data center needs to be able to respond and manage the highly dynamic nature of cloud resource utilization

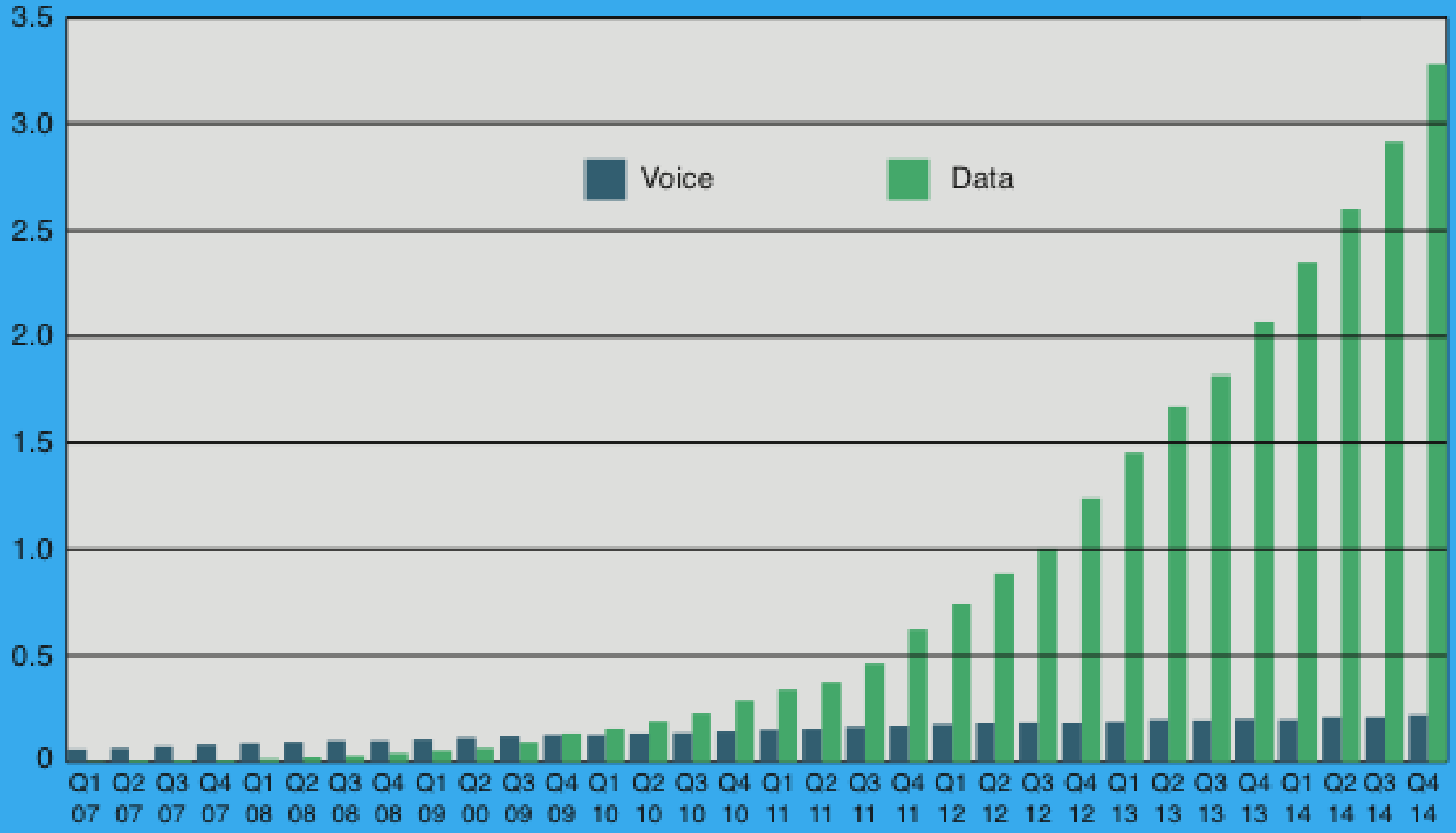

Figure 2.5 World Total Monthly Mobile Voice and Data Traffic (exabytes/month) [AKAM15]

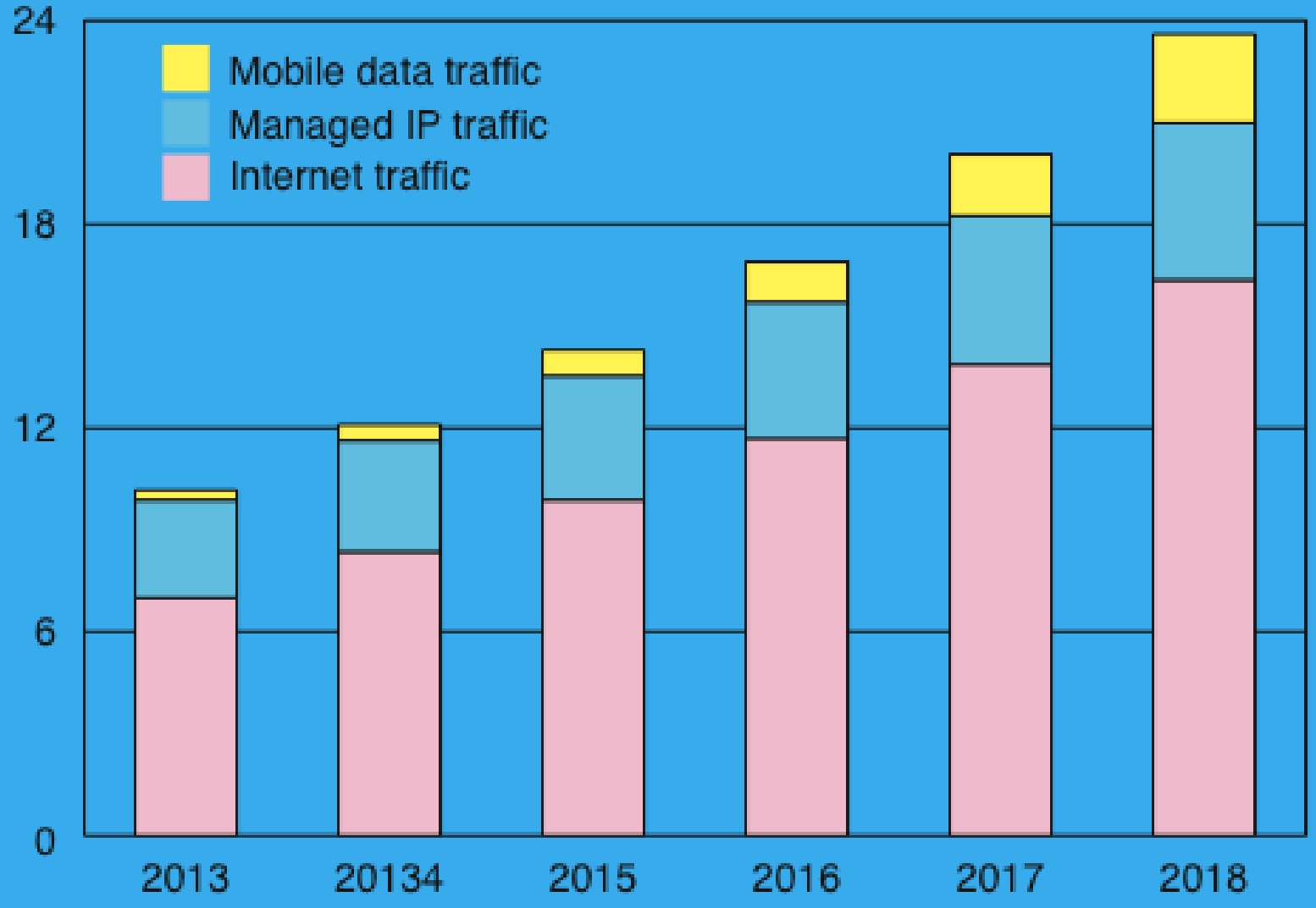

Figure 2.6 Forecast Monthly Enterprise IP Traffic (exabytes/month) [CISC14]

Quality of Service (QoS)

- The measurable end-to-end performance properties of a network service, which can be guaranteed in advance by a service level agreement (SLA) between a user and a service provider, so as to satisfy specific customer application requirements

Commonly specified properties include:

- Throughput
- Delay
- Packet jitter
- Error rate
- Packet loss
- Priority
- Availability
- Security

Quality of Experience (QoE)

- A subjective measure of performance as reported by the user; relies on human opinion
- Is important particularly when dealing with multimedia applications and multimedia content delivery
- QoS processes by themselves are not sufficient in that they do not take into account the user's perception of network performance and service quality
- Categories of factors and features that can be included in QoE are:
  - Perceptual
  - Psychological
  - Interactive

Routing Characteristics

- The primary function of an internet is to accept packets from a source station and deliver them to a destination station
  - To accomplish this, a path or route through the network must be determined
  - Generally, more than one route is possible; therefore, a routing function must be performed
- Selection of a route is generally based on some performance criterion
  - Simplest criterion is to choose the minimum-hop route (one that passes through the least number of nodes) through the network
  - A generalization of the minimum-hop criterion is least-cost routing; in this case, a cost is associated with each link, and, for any pair of attached stations, the route through the network that accumulates the least cost is sought

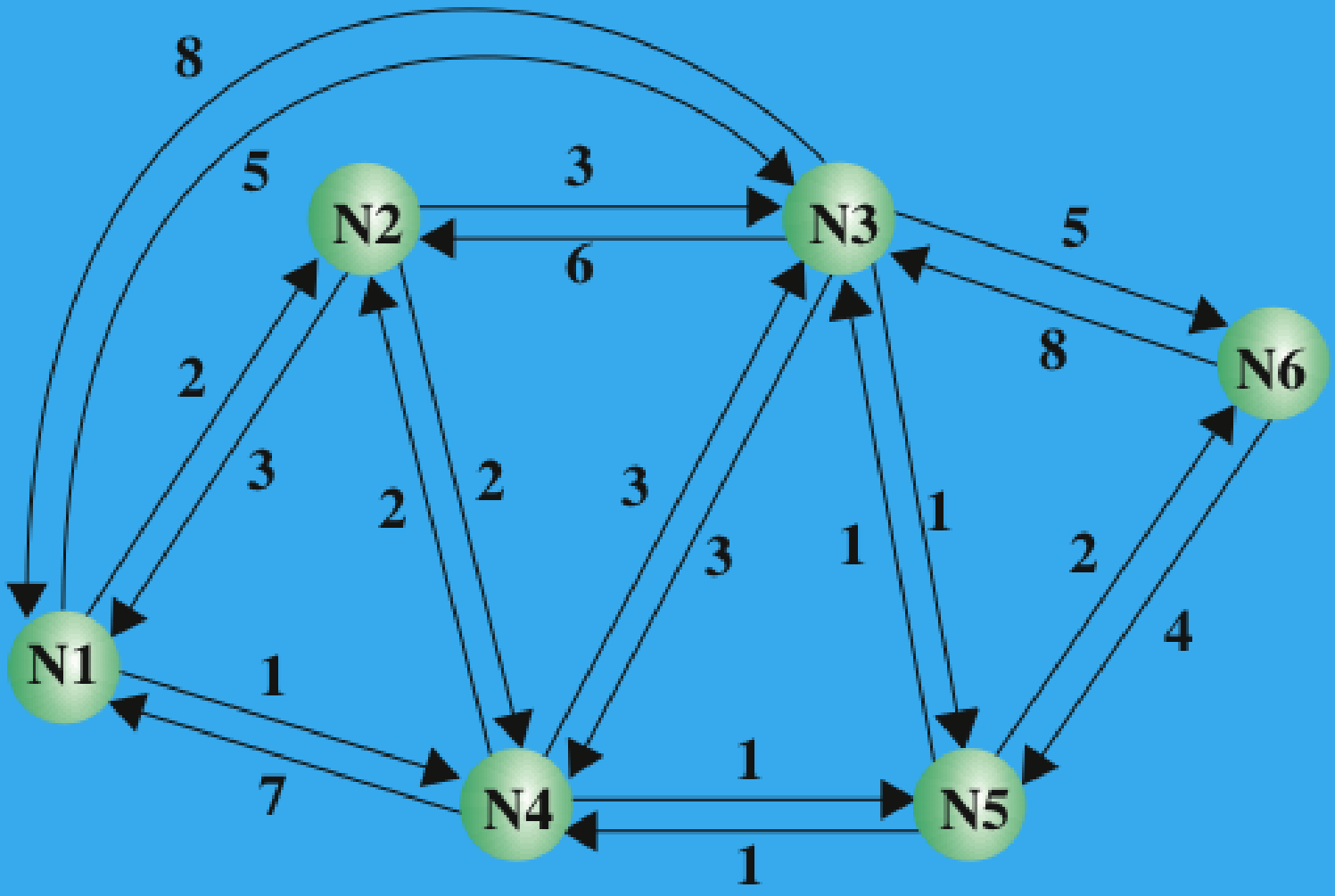

Figure 2.7 Example Network Architecture

CENTRAL FORWARDING TABLE

To Node \ From Node	1	2	3	4	5	6
1	—	1	5	2	4	5
2	2	—	5	2	4	5
3	4	3	—	5	3	5
4	4	4	5	—	4	5
5	4	4	5	5	—	5
6	4	4	5	5	6	—

Node 1 Table

Destination	Next Node
2	2
3	4
4	4
5	4
6	4

Node 2 Table

Destination	Next Node
1	1
3	3
4	4
5	4
6	4

Node 3 Table

Destination	Next Node
1	5
2	5
4	5
5	5
6	5

Node 4 Table

Destination	Next Node
1	2
2	2
3	5
5	5
6	5

Node 5 Table

Destination	Next Node
1	4
2	4
3	3
4	4
6	6

Node 6 Table

Destination	Next Node
``	5
2	5
3	5
4	5
5	5

Figure 2.8 Packet Forwarding Tables (using Figure 2.7)

Routing Protocols

- Routers are responsible for receiving and forwarding packets through the interconnected set of networks
- Each router makes routing decisions based on knowledge of the topology and traffic/delay conditions of the internet
- A degree of dynamic cooperation is needed among the routers
- The router must avoid portions of the network that have failed and should avoid portions of the network that are congested

Routing Protocols

- There are essentially two categories of routing protocols which are based on the concept of an autonomous system (AS)
- An AS exhibits the following characteristics:
  - An AS is a set of routers and networks managed by a single organization
  - An AS consists of a group of routers exchanging information via a common routing protocol
  - Except in times of failure, an AS is connected (in a graph-theoretic sense)
- An interior router protocol (IRP) is a shared routing protocol that passes routing information between routers within an AS

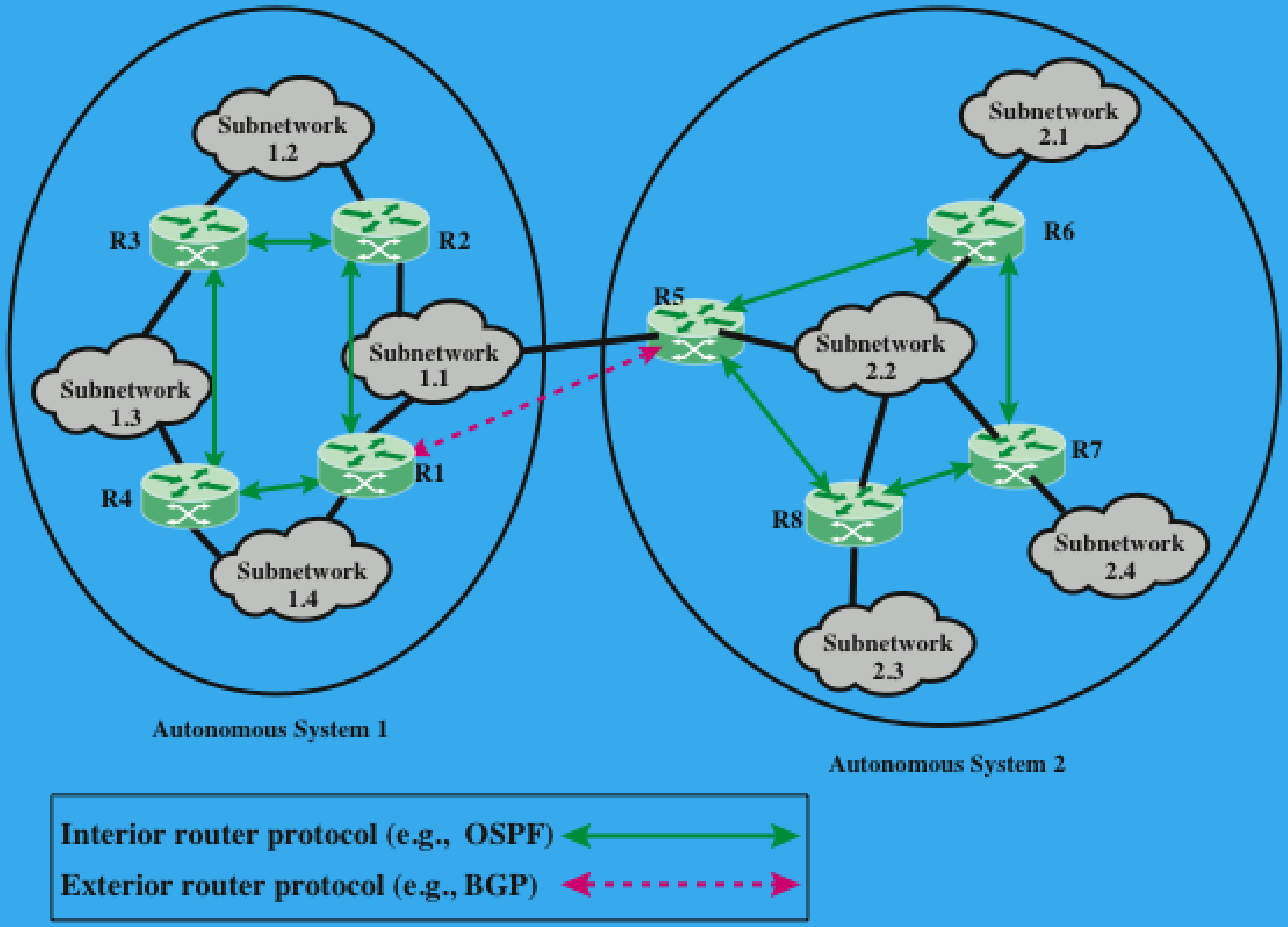

Figure 2.9 Use of Exterior and Interior Routing Protocols

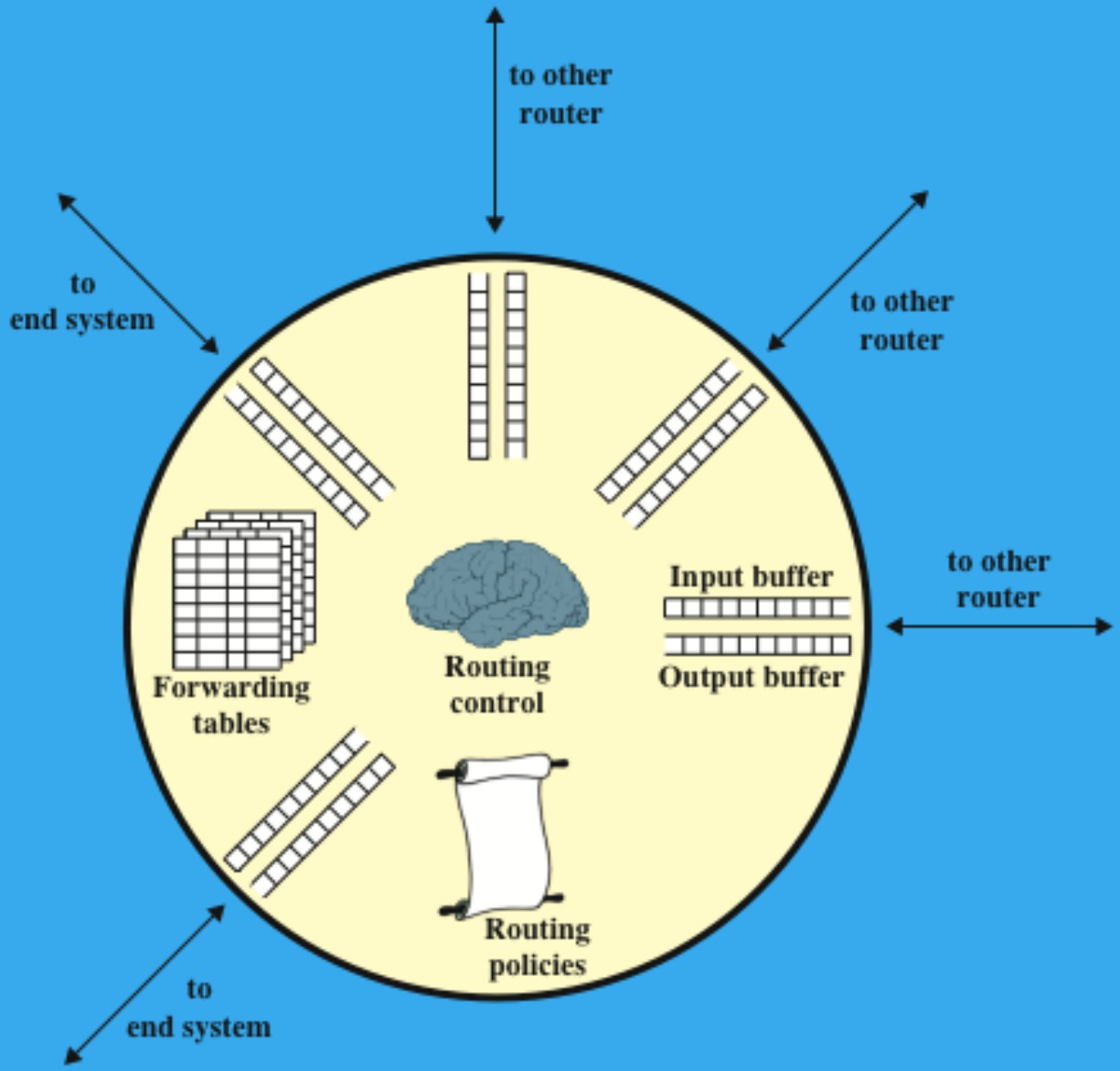

Figure 2.10 Elements of a Router

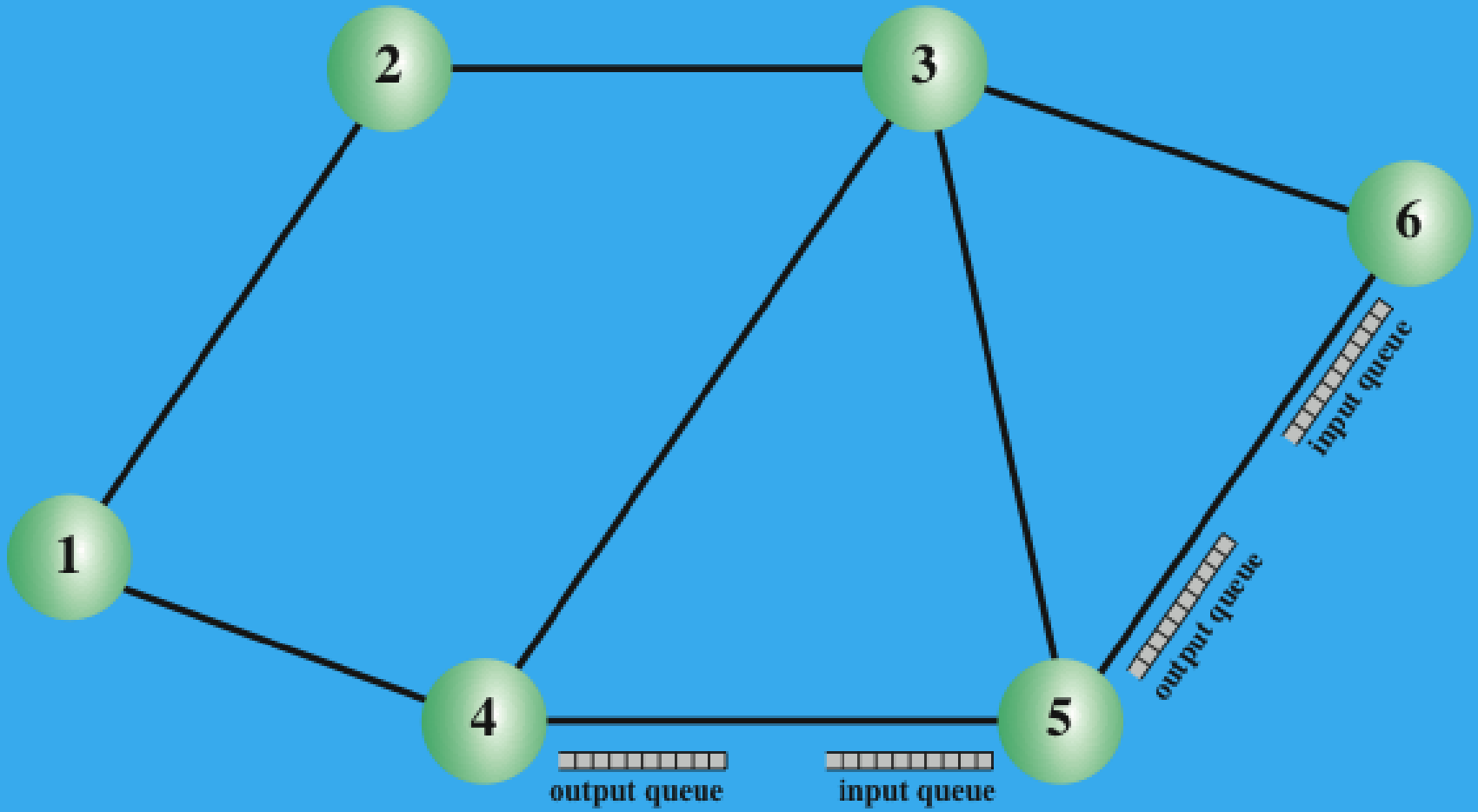

Figure 2.11 Interaction of Queues in a Data Network